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THE QUESTION OF THE EVOLUTION OF TYPHOONS

- USSR -

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/Following is a translation of an article by A. V. Sharapov in the Russian-language periodical Trudy dal'nevostochnogo nauchno-issledovatel'skogo gidrometeorologicheskogo instituta (Works of the Far Eastern Scientific Research Hydrometeorological Institute), Moscow, No. 7, 1959, pages 33-45./

This article is based on material from two voyages of the expeditionary ship "Vityaz'" of the Institute of Oceanology of the Academy of Sciences of the USSR made from 12/9 to 5/11 1955 (22nd voyage) and from 29/6 to 11/10 1957 (25th voyage; it was the very first voyage on the program for the International Geophysical Year).

Both trips were made in the northwestern part of the Pacific Ocean. On the 22nd trip, the navigation area was bound on the east by 150° E long. and a latitude of the north tropic and, on the 25th voyage the "Vityaz'," sailing approximately along 154° E long., reached 9° S lat.

One synoptic map for 0900 hours Moscow time and a chart of the synoptic situation in accordance with the RMTs /radiometeorologicheskiy tsentr -- radio meteorological station/ Tokyo at 2100 hours were compiled daily during the 22nd voyage. Two maps were plotted on the 25th voyage: at 0300 hours and at 1500 hours and a chart for 2100 hours.

Pressure values in the center of the typhoons and wind velocities in their zone were taken from information from the Japanese meteosluzhba /meteorologicheskaya sluzhba -- meteorological service/.

The following four stages in the development of typhoons were determined in forecasting designed to ensure ship navigation safety:

1. Tropical Depression Stage (beginning). This is the stage in the development of a typhoon which begins from the moment of birth and continues throughout the entire time that the pressure at the center of the typhoon remains at no less than 1,000 mb, and its area is defined by only one closed isobar (a multiple of five). Maximum wind velocity at the center of the depressions did not exceed 15-17 m/sec (30-33 knots).

2. Typhoon Proper Stage. This stage obtains from the moment that the depression deepens to a value which is less than 1,000 mb, and is defined by at least two closed isobars until such time as the typhoon is transformed[1] /See Note/ into a polar front cyclone, that is, if this transformation has taken place. As a rule, typhoons have reached their maximum development and depth at this stage. Wind velocity at the center of typhoons at this stage have reached 40-45 m/sec, and 65-75 m/sec in the deepest of them. /Note: It seems to us that the term "regeneration," which is used to signify this process, is not very accurate; therefore, in the future, the term "transformation" will be used, conforming to the early works of S. P. Khromov[3].

3. Stage at Which Typhoon Becomes Polar Front Cyclone. A change in many characteristics of the typhoon and primarily a change in the direction and speed of its movement is linked with this stage. During this stage, a typhoon becomes thermally asymmetric.

As a rule, typhoons which are in the second stage of development undergo the process of transformation, but three instances of the transformation of tropical depressions have been noted.

4. Transformed Typhoon Stage. In this stage a typhoon is, in essence, a polar front cyclone formed from masses of air brought by the typhoon and from masses of air from moderate latitudes. A transformed typhoon has all the qualities of a polar front cyclone, and, in addition, is usually characterized by considerable depth and energy.

A map of the area under consideration indicating the trajectory of the typhoons observed and the stages of their development is shown in Figure 1.

Five typhoons (Table 1) were detected during the 22nd voyage, which obtained for 55 days, and their development was tracked. A total of 22 tropical depressions were noted.

Table 1

Typhoons Observed During the 22nd Voyage of the Expeditionary Ship, Vityaz' (12/9-5/11 1955)

Typhoons in Order of Their Rise	Period of Occurrence of Typhoons in Area Under Investigation
1	17-23/9
2	20/9-1/10
3	26/9-5/10

Typhoons in Order of Their Rise	Period of Occurrence of Typhoons in Area Under Investigation
4	4-12/10
5	15-21/10

During the 25th trip, lasting 105 days, 10 typhoons (Table 2) and a total of 51 tropical depressions were noted.

Table 2

Typhoons Observed During the 25th Trip of the Expeditionary Ship, Vityaz' (29/6-11/10)

No of Typhoons in Order of Their Rise	Name of Typhoons	Period of Occurrence of Typhoons in Area Under Investigation
1	--	11-15/7
2	Agnes	9-22/8
3	Bess	23/8-8/9
4	Carmen	5-14/9
5	Della	10-17/9
6	Elaine	11-19/9
7	Faye	16-29/9
8	--	16-20/9
9	Hester	3-10/10

Note. The Japanese and American meteorological service give a feminine name to typhoons as soon as they become "class A," that is, as soon as they threaten navigation. Table 2 shows these names which have been adopted in radio communiques for the majority of typhoons. In the future, their names will be used to signify these typhoons.

Table 3 shows the distribution of typhoons according to months. Analogous data for tropical depressions are indicated in Table 4.

Table 3

Distribution of Typhoons According to Months

Period of Observation	Months 7	8	9	10	Total
1955 (12/9-5/11)	--	--	3	2	5
1957 (29/6-11/10)	1	2	5	1	9

Table 4

Distribution of Tropical Depressions According to Months

Period of Observation	Months 7	8	9	10	11	Total
1955 (12/9-5/11)	--	--	11	10	1	22
1957 (29/6-11/10)	10	21	17	3	--	51

Unfortunately, because of the fact that the navigation periods do not coincide it is impossible to compare the repetitiousness of typhoons and tropical depressions during the 22nd and 25th voyages. The more complete materials from observations in 1957 indicate that the maximum number of depressions was observed in August-September, and of typhoons -- in September.

Let us review the main characteristics of typhoons for each of the four stages of their development (Tables 5-8).

First Stage. Tropical Depression

Data concerning tropical depressions are quoted in Table 5. According to material from both voyages the rise of 10 typhoons was observed. The exact spot of origin of three typhoons during the voyage of 1955 was not able to be determined because of the scarcity of meteorological data on regions adjacent to the equator. However, they were detected still in the stage of a depression shortly after origin -- probably, on the second or third day of their existence. Therefore, the place of origin of these depressions can be approximated at 300-500 miles to the southeast of the place of their original detection on the map. And only the typhoon

of 1957, Della, penetrated the limits of the investigated area from the east along the parallel 19° N lat. and already in the second stage of development with a pressure of 978 mb in the center.

During inspection of the originating places of typhoons they succeeded in detecting two well localized originating areas of depressions from which typhoons developed later on.

One of the originating places of typhoons is the area in the eastern part of the Caroline archipelago bound by 160 and 150° E long., and on the south and north by 3 and 10° N lat. The origin of five typhoons was pin-pointed in this area. If you take into consideration that three depressions in 1955, as we have already said, were detected 2-3 days after birth, one can assume that 8 depressions arose in this area or near it. This also becomes evident when the map of the trajectories of typhoons is inspected (Figure 1).

The second originating area of typhoons is the area to the east of the Philippine Islands bound on the east by the 134° meridian, and on the south and north by 10 and 18° N lat. Five typhoons arose in this area.

As we have indicated, the rise of typhoon Della took place somewhere considerably to the east of the 180° meridian.

When the originating field of all tropical depressions was investigated during both voyages it could be observed that the area of their origin is a strip bound on the south by the equator, and on the north by 15° N lat., and that this strip stretches from the 180° meridian to the Philippine Islands. In the area of the Philippines it rises a little to the north bound by the 5 and 20° N lat. However, depressions arose most frequently within this strip in the area of the eastern islands of the Caroline archipelago and to the east of the Philippines.

The depression stage lasted 2-5 days. Only in one case (typhoon Carmen), when the depression was transformed into a polar front disturbance before the onset of the second stage, did the depression stage last one day.

The life of depressions which do not develop into typhoons was 1-3 days. Only two depressions lasted about five days. One of these depressions having traveled all the way from 173 to the 148° E long. joined typhoon Hester at 10° N lat. The second depression, which blew up from 10° N lat. from the area to the south of the Marianna Islands to 20° N lat. at 134° E long., filled up, probably, because of the swift development of typhoon Bess over the north of the Marianna Islands.

In the first stage of the development of typhoons, pressure in the center varied from 1,008 to 1,000 mb, and in all cases it decreased with the passage of time.

Table 5

Main Characteristics of Typhoons
According to Stages in Their Development

I. Tropical Depression Stage

No of Typhoons in Order of Their Rise	Name of Typhoon	Period of Stage	Coordinates of Place of Origin N lat. (in degrees)	E long. (in degrees)
		1955		
1	--	(15)*-20/9	(8)	(151)
2	--	(19)-21/9	(9)	(154)
3	--	(24)-28/9	(5)	(151)
4	--	4-6/10	16	134
5	--	15-17/10	18	129
		1957		
1	--	11-13/7	12	130
2	Agnes	9-13/8	5	150
3	Bess	23-27/8	10	159
4	Carmen	5-6/9	13	126
5	Della	--	--	--
6	Elaine	11-15/9	3	151
7	Faye	16-18/9	8	152
8	--	16-18/9	13	132
9	Hester	3-5/10	6	152

[Adjoins page 7 here.]

* In this and subsequent tables, numbers in parenthesis indicate hypothetical data.

Pressure Value in Center (in mb)	Diameter of External Isobar (in miles)	Direction of Shift (in degrees)	Speed of Shift (miles/ days)	Duration of Stage (in days)
1,104	240-300	290	340	(5)
1,006-1,000	180-300	315	225	(3)
1,006-1,000	180-420	325	210	(4)
1,004	240-300	325	120	2
1,008	420	315	150	2
1,006-1,005	240-480	320	170	2
1,006-1,003	300-420	310	240	4
1,008-1,004	240-300	315	240	4
1,005	240-300	340	180	1
--	--	--	--	--
1,006-1,000	--	310	255	4
--	--	--	--	2
1,006-1,004	--	300	150	2
1,008-1,005	340-480	300	270	2

[Adjoins page 6 here.]

The depth of the depressions which did not develop into typhoons varied from 1,010 to 1,005 mb; however, in an overwhelming majority of them, the pressure equaled 1,008-1,006 mb.

The diameter of the depressions at the moment of origin and during the first days of existence was 200-300 miles, and 300-500 miles at the end of the first stage.

The direction of the typhoons during the depression stage was 290-340°; that is, on the whole, they were moving to the northwest. Their speed varied from 120-340 miles per day.

An interesting peculiarity should be emphasized: depressions which arose in the second area (to the east of the Philippines) had a much lower speed -- 120-180 miles a day. The speed of those depressions which originated in the first area (eastern islands of the Caroline archipelago) was 210-270 miles a day, and the speed of one depression which arose in this area even reached 340 miles a day. The latter depression later on developed into a typhoon and, not becoming transformed, moved along the 15° parallel N lat. to the west in the area of Indochina.

It should be noted that all depressions which later on developed into typhoons moved with the greater northern component than the depressions which did not become typhoons. The speed of these and others was approximately the same.

In all cases of the origin of depressions, a frontal section could be detected in their system. First of all, it was quite clearly detected in the wind field separating the northeastern tradewind of the northern hemisphere from the southeastern tradewind of the southern hemisphere. As far as temperature is concerned, a frontal section was not so clearly expressed. Rain was observed along the front more often than outside its zone.

The line of the frontal section stretched from the east to the west along the latitude of the origin of depressions, riding a little in the region of the Philippine Islands somewhat to the northwest.

The origin of depressions in the southern hemisphere in the region to the north of the Solomon Islands was detected during the 25th voyage. One of the depressions arose on 18/7 in the region of the Lyra reef with pressure at the center about 1,010 mb. By 19/7 this depression moved to the south-southwest, somewhat to the south of the island of New Britain and then, after it had changed direction to the southeast it went to the west of the island of New Guinea in the Coral Sea. The second depression was slow to form; it also had a pressure of 1,010 mb, and on 23-24/7 it was located to the north of the Solomon Islands. During this period (winter in the southern hemisphere) an anticyclone, which was very stable and was well tracked on synoptic maps, formed in Australia.

Quite sharply expressed frontal sections could also be detected in the depressions of the southern hemisphere. Cold air, in whose system a spur of the Australian anticyclone was formed, pervaded the cold front of these depressions to the northwest. Cooling, caused by the flow of cold air, was well tracked both on earth and at elevations up to 200 mb. A strengthening of the southeastern winds was observed and an increase in cloudiness and precipitation.

Second Stage. Typhoon

Data concerning typhoons in their second stage of development are cited in Table 6. The second stage in 11 out of 14 typhoons was observed prior to the transformation of the typhoon into a polar front cyclone. In three cases, depressions which did not develop into typhoons were first transformed into polar front waves and had then already developed prior to the typhoon stage.

Typhoons from the tropical depression stage became deeper in the strip between the 10 and 24° N lat., and the typhoons from depressions which arose in the area to the east of the Caroline Islands deepened between 10 and 18° N lat. and six of them (out of eight) deepened at 15-18° latitude and only two typhoons at latitudes of 10-11°. Typhoons from depressions which arose in the region to the east of the Philippines depened at latitudes of 15-24° N lat.; however, 4 typhoons out of 5 deepened at latitudes of 19-24°, and only one at 15° N lat.

The second stage of development of typhoons is characterized by their swift deepening. Sometimes pressure in the center of the typhoon falls several hundreds of millibars. Thus, typhoon Agnes from 0300 hours 14/8 to 0300 hours 15/8 1957 deepened from 1,000 mb to 960 mb, and typhoon Hester went from 970 to 910 mb from 0300 hours 7/10 to 0300 hours 8/10 1957.

As we have pointed out, typhoons in the second stage of development are more intensive, and their maximum depth is noted in just that stage. Typhoons reached their greatest depth on the 2-6 day from the beginning of the second stage, while 8 typhoons out of 13 reached it on the 2-3 days, and 5 typhoons on the 4-5 days.

Typhoons reached their greatest depth in the zone from 13 to 28° N lat., while the majority of typhoons (9 out of 13) reached it between 19 and 24° N lat.; only 3 typhoons at about 27-28° N lat., and 2 typhoons at 13 and 17° N lat.

Areas occupied by typhoons (counting by the last closed isobar) were not equivalent under identical pressure values at their centers. Thus, typhoon Agnes, at the beginning of the second stage with a pressure of about 1,000 mb at the center, had a

Table 6

Main Characteristics of Typhoons
According to Stages of Their Development

II. Typhoon Stage

No of Typhoons in Order of Their Rise	Name of Typhoon	Period of Stage	Coordinates of Deepening Place in Typhoon		Pressure Value in Center (in mb)
			N lat. (degrees)	E long. (degrees)	
		1955			
1	--	21-24/9	16	129	990-930
2	--	22-29/9	17	146	990-930
3	--	29/9-3/10	16	139	1,000-975
4	--	8-10/10	22	138	990-975
5	--	(18-20/10)	24	126	995-985
		1957			
1	--	13-15/7	19	126	1,000-995
2	Agnes	14-21/8	15	139	1,000-910
3	Bess	28/8-5/9	18	147	990-950
4	Carmen	9-13/9	22	130	990-960
5	Della	10-15/9	(19)	(180)	980-960
6	Elaine	15-17/9	16	142	990-950
7	Faye	18-24/9	10	148	980-935
8	--	19-21/9	15	128	1,000-980
9	Hester	5-8/10	11	145	990-910

[Adjoins page 11 here.]

Diameter of External Isobar (in miles)	Direction of Shift (degrees)	Speed of Shift (miles/day)	Duration of Stage (days)	Coordinates of Site of Typhoon at Greatest Depth	
				N lat. (degrees)	E long. (degrees)
720-1,200	275	240	3	17	122
600-1,080	345	197	7	24	141
480- 720	335	240	5	23	137
780-1,020	350	210	2	28	136
480- 720	--	--	--	27	129
720- 960	300	300	2	19	120
660-1,080	330	200	8	24	130
660-1,380	315	190	9	27	139
900-1,260	270	150	5	20	122
--	295	370	4	24	155
--	340	300	2	19	141
360- 780	295	280	6	13	141
--	295	370	2	20	120
900- 780	335	260	3	23	141

[Adjoins page 10 here.]

diameter of approximately 660 miles, and typhoon Faye, with a pressure of 980 mb at her center, was 360 miles in diameter. Typhoon Agnes, which deepened to 910 mb, increased in diameter to 1,100 miles, and typhoon Faye with a pressure of 935 mb increased in diameter to 800 miles.

The largest in area was typhoon Bess. Her diameter approximated 1,400 miles with a pressure of 950 mb at the center. The two deepest typhoons -- Agnes and Hester -- with a pressure of 910 mb were somewhat less in diameter -- about 1,100 miles.

In this way, it can be computed that the diameter of typhoons varies from 360 to 900 miles in the initial phase of the second stage, and from 800 to 1,400 miles at the moment of maximum depth.

From the moment typhoons pass into the second stage they frequently begin to move with the greater northern component. Thus, out of 9 typhoons for which it was possible to compare the direction in the first and second stages the direction of 6 in the second stage swerved to the north 15-35° and it shifted in the opposite direction 5-10° in only 3. On an average, the general direction of typhoons in the second stage was northwesterly.

It is interesting to note that with rare exception all typhoons swerve sharply to the north just before they become very deep. Examples of this are typhoons No. 2 and 3 in 1955 and typhoons Agnes, Bess, Elaine, and Hester in 1957. The speed of the typhoons was somewhat higher than in depressions, and varied from 150-370 miles a day. The most characteristic speed of typhoons was 190-300 miles a day and this speed was noted in 10 typhoons; 2 typhoons moved at a speed of 370 miles a day, and only one typhoon -- Carmen -- which had a very complex trajectory moved at a speed of 150 miles a day.

Third Stage. Transformation of a Typhoon Into a Polar Front Cyclone

Data concerning typhoons in the third stage of their development are cited in Table 7. Eleven out of 14 typhoons underwent the transformation stage. In 3 typhoons, the transformation stage was not observed within the boundaries of the area under investigation. These typhoons subsequently moved to the west between 17 and 22° N lat. in the region of southern China. Two of these 3 typhoons arose to the east of the Philippines, and one came from even a more easterly region. The depth of the typhoons reached 995-930 mb.

In 3 typhoons out of 11 which underwent transformation the transformation process happened twice (typhoons No. 4 and 5 in 1955 and Carmen in 1957). In all three instances the first transformation was a transformation of tropical depressions into polar

Table 7

Main Characteristics of Typhoons
According to the Stages of Their Development

III. Transformation Stage

No of Typhoons in Order of Their Rise	Names of Typhoons	Dates of Trans-formation	Coordinates of Transformation Site	
			N lat. (degrees)	E long. (degrees)
		1955		
1	--	--	--	--
2	--	29/9	30	131
3	--	3/10	31	133
4'	--	6/10	18	131
4	--	10/10	28	136
5	--	17-18/10	22	126
		1957		
1	--	--	--	--
2	Agnes	21/8	34	127
3	Bess	5-6/9	31	131
4'	Carmen	6/9	16	126
4	"	13/9	20	122
5	Della	15/9	30	156
6	Elaine	17/9	23	138
7	Faye	24-25/9	23	122
8	--	--	--	--
9	Hester	8/10	23	141

[Adjoins page 14 here.]

Note: 4' -- transformation of a tropical depression into a polar front wave.

Pressure Values in Center (in mb)						
Before Transformation	After Transformation	Difference	Diameter of External Isobar	Direction of Shift (degrees)	Speed of Shift (miles/days)	Duration of Stage (in days)
--	--	--	--	--	--	--
960	970	10	1,020	--	--	< 1
975	1,000	25	600	--	--	< 1
1,000	1,000	0	420	--	--	< 1
975	975	0	1,020	--	--	< 1
1,000	985	- 15	480	10	120	1
--	--	--	--	--	--	--
970	980	10	1,200	--	--	< 1
960	990	30	1,200	10	165	1
1,005	1,005	0	300	--	--	< 1
960	965	5	1,200	--	--	< 1
960	965	5	--	--	--	< 1
960	970	10	--	--	--	< 1
995	950	- 45	600	55	120	1
--	--	--	--	--	--	--
910	940	30	900	--	--	< 1

[Adjoins page 13 here.]

front waves. All 3 depressions arose in the second area of origin of typhoons -- to the east of the Philippines. Their transformation into polar front waves took place on the 2-3 day from origin. After the depressions, which up until this moment had been moving to the northwest, had been transformed, they changed their direction to the north or northeast and, like ordinary wave disturbances, they moved along the front, scarcely becoming deeper.

However, within 2 days after the first transformation a new change in 2 waves occurred in their direction: from the northeast to the north in the first instance (typhoon No. 4 1955), and in the second (Carmen) -- to the northwest and subsequently even to the southwest.

A second transformation of the latter two typhoons occurred on the 4th and 7th days respectively after the first. After the second transformation, the first of the typhoons (No. 4 1955), after it had increased its speed considerably, again moved to the northeast; typhoon Carmen, whose second transformation took place on Taiwan, changed her direction from the southwest to the northwest and went out to China where it filled up. The evolution process of Carmen is, in general, unique and did not resemble the evolution of other typhoons, and this requires special investigation. The second transformation of the third typhoon (No. 5 1955) evidently coincided with the beginning of its development into the second stage. With a pressure of 1,000 mb at its center at the time of the first transformation she deepened to 885 mb in 2 days and, after she changed direction first to the north and then to the northeast, she quickly left the boundaries of the investigated area.

The remaining 8 typhoons underwent the process of transformation only once. At the time of transformation they were all well developed typhoons (second stage). By the time of transformation 5 typhoons had already gone through the period of maximum development lasting from 1-5 days and had begun to fill up; pressure at their center grew 10-60 mb. In 5 typhoons the moment of transformation coincided with the period of their maximum depth.

The transformation of typhoons into polar front cyclones occurred in the zone from 20-34° N lat. The transformation of the depressions into polar front waves took place in more southern regions, at 16-18° N lat. The transformation region was bound by 142° on the east and 120° on the west E long. Only typhoon Della, which must be attributed to another group of typhoons because of place of origin, was transformed at 155° E long.

It must be noted that in general the center of transformation regions move to the south and east from August to October. Thus, in August the transformation of typhoons Agnes and Bess took place at 34 and 31° N lat. 127 and 131° E long., respectively, while the transformation of typhoon Hester occurred in October at

23° N lat. and 141° E long., which was evidently linked with the more southeasterly position of the polar front during this period.

The area occupied by typhoons at the time of transformation was practically equal to their area during the days prior to transformation.

As a rule, the process of transformation lasted less than a day and sometimes (in three instances) about a day. In these last instances the speed of the typhoon slowed down to 120-165 miles a day, and the direction gradually changed from the northwest or west to north and northeast.

Fourth Stage. Transformed Typhoon

Data concerning typhoons in the fourth stage of their development are shown in Table 8. After typhoons have been transformed (including depressions) into polar front cyclones, a sharp change in direction to the right is most characteristic; that is, to the northeast, as well as a considerable increase in speed.

The deflection angle of the trajectory varied from 30-130° if the typhoon moved in the direction of 295-350° in the second stage, after transformation their direction had an azimuth of 20-65° (excluding Carmen whose unusualness has been mentioned above). The speed of typhoons after transformation increased 2-6 times and reached 660-1,200 miles a day.

Attention should be paid to the fact that the greater eastern component, as it moves in a northeasterly direction in the polar front cyclone stage, corresponds to the greater western component of typhoon movement.

Within the next few days after transformation, the pressure in the center of the typhoons grew or remained without any significant change in a majority of cases. Thus, in 8 cases of typhoon transformation (out of 11) pressure increased 5-30 mb, in one case it remained without change, and only in 2 cases did it fall 15 and 45 mb. In our opinion, one of these anomolous cases was typhoon No. 5 in 1955 in whom the beginning of the second stage coincided with the time of its transformation into a polar front cyclone. The second case was the transformation of typhoon Faye.

The occurrence period of transformed typhoons over the territory of the area under investigation lasted from 1-4 days. However, in the majority of the typhoons this period lasted 2 days. Typhoons (cyclones) after transformation continued to move in a northeasterly direction and crossed 43° N lat. between 132° and 168° E long., and typhoon Della farther to the east at 180° E long. However, the majority of the typhoons (7 out of 10) crossed 43° N lat. within 132-150°.

As a rule, while the typhoons were moving toward 43° N lat., beginning from the time of transformation, they continued to fill up. In 9 out of 10 typhoons pressure increased from the time of transformation 5-50 mb and only in one (No. 4 1955) did it fall 10 mb.

As a rule, the area occupied by transformed typhoons decreased somewhat compared to the area at the time of transformation, or remained without any significant changes. Only in 3 cases did it increase to any appreciable extent: at the moment of transformation the diameter of the last closed isobar in typhoons No. 5 1955 was 480 miles, and in the cyclone stage it increased to 720 miles; in typhoon Hester it grew correspondingly from 900-1,380 miles, and in typhoon No. 4 1955 -- 1,020-1,260 miles. In four typhoons the diameter decreased 120-300 miles and in the other four it remained practically unchanged.

One may assume that an increase in the area of transformed typhoons (cyclones) occurs later on during their regeneration into a new polar front which is, as a rule, farther to the north of 40° N lat. In an examination of daily synoptic maps such a picture was established for typhoon Hester which, after it became a polar front cyclone, at 23° N lat., went to the region of the Kuril Islands and here was twice regenerated into a new polar front.

The total period of development of typhoons from the moment of birth to the moment they crossed 43° N lat. (in event of a transformation process) or crossed the 120° meridian (in event transformation process had not taken place) lasted 4-16 days. The shortest stay in the area under investigations (4 days) occurred in typhoons which originated in the region to the east of the Philippines and which were not transformed (2 typhoons). The life of one typhoon which originated in the region of the eastern part of the Caroline Islands and which was not transformed was 8 days. Typhoons which originated to the east of the Philippines and which were transformed into polar front cyclones lasted 6-9 days (3 typhoons).

The life of 7 typhoons which originated to the east of the Caroline Islands and which passed through the entire cycle of development varied from 7-16 days. Out of these typhoons, typhoons Elaine and Hester, who had moved from the moment of birth along the most eastern trajectory and with the larger western component, had the shortest period of development (7-8 days). In the remaining 5 typhoons of this group the period of development lasted 11-16 days. They moved with the greater western component. The last typhoon (Della) was tracked for 7 days over the area under investigation.

Table 8

Chief Characteristics of Typhoons
According to Stages of Their Development

IV. Cyclone Stage

No of Typhoons in Order of Their Rise	Name of Typhoon	Period of Occurrence of Cyclone in Territory Under Investigation	Pressure Values in Center (in mb)
		1955	
1	--	--	--
2	--	30/9-1/10	970- 990
3	--	4-5/10	1,000
4'	--	6-8/10	1,000
4	--	10-12/10	975- 965
5	--	18-21/10	985- 994
		1957	
1	--	--	--
2	Agnes	21-22/8	980
3	Bess	6-8/9	990
4'	Carmen	6-8/9	1,005-1,002
4	"	13-14/9	965
5	Della	15-17/9	965- 980
6	Elaine	17-19/9	970- 994
7	Faye	25-29/9	950-1,000
8	--	--	--
9	Hester	8-10/10	940- 960

/Adjoins page 19 here./

Note: 4' -- polar front wave.

Diameter of External Isobar (in miles)	Direction of Shift (in degrees)	Speed of Shift (miles/days)	Duration of Cyclone Within Area Under Investigation (in days)
--	--	--	--
900	25	780	2
840	30	660	2
420	60	240	2
900-1,260	30	690	2
480- 720	40	780	3
--	--	--	--
700- 900	25	840	1
1,200	45	1,200	2
360	55	210	2
1,080	320	240	1
--	60	660	2
--	40	1,020	2
600	65	750	4
--	--	--	--
1,380	20	1,020	2

[Adjoins page 18 here.]

Conclusions

1. Four possible stages of development of typhoons were distinguished.

2. Tropical depressions, which later developed into typhoons, arose in two areas: in the eastern part of the Caroline archipelago and to the east of the Philippine Islands (over the Philippine crater).

3. Depressions which arose in the region of the Caroline archipelago had a speed 1.5-2 times greater than depressions which arose near the Philippine Islands.

4. Typhoons which developed from depressions arising in the region of the Caroline archipelago were notable for their much greater depth.

5. Depressions which arose to the east of the Philippine Islands sometimes underwent a first transformation into polar front waves. If this process occurred south of 20° N lat. the development of polar front waves into typhoons with a subsequent second transformation into polar front cyclones was observed, as a rule, after approximately 2 days.

6. According to more complete material received on the second voyage, about 16% of all the depressions noted developed into typhoons.

7. About 80% of all the typhoons encountered were transformed into polar front cyclones.

8. The term "regeneration of a typhoon into a polar front," which is used in literature and synoptic practice, should not be considered as very accurate since a typhoon also assumes a new qualitative condition, and regeneration, which signifies a restoration of the former condition, is not observed. It is more expedient to use the term "transformation of a typhoon" since it expresses the existence of a process more accurately.

9. Depressions which later developed into typhoons moved with greater northern component more than depressions which did not develop into typhoons.

10. As a rule, in their movement typhoons turned somewhat to the north just prior to the moment of their greatest depth.

11. Within 1-2 days after the beginning of the transformation of a typhoon one may expect it to swerve to the northeast and to increase its speed sharply.

12. The greater the western component of the speed of typhoons prior to the moment of transformation, the greater the angle of deflection of its trajectory to the northeast after transformation.

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FIGURE APPENDIX

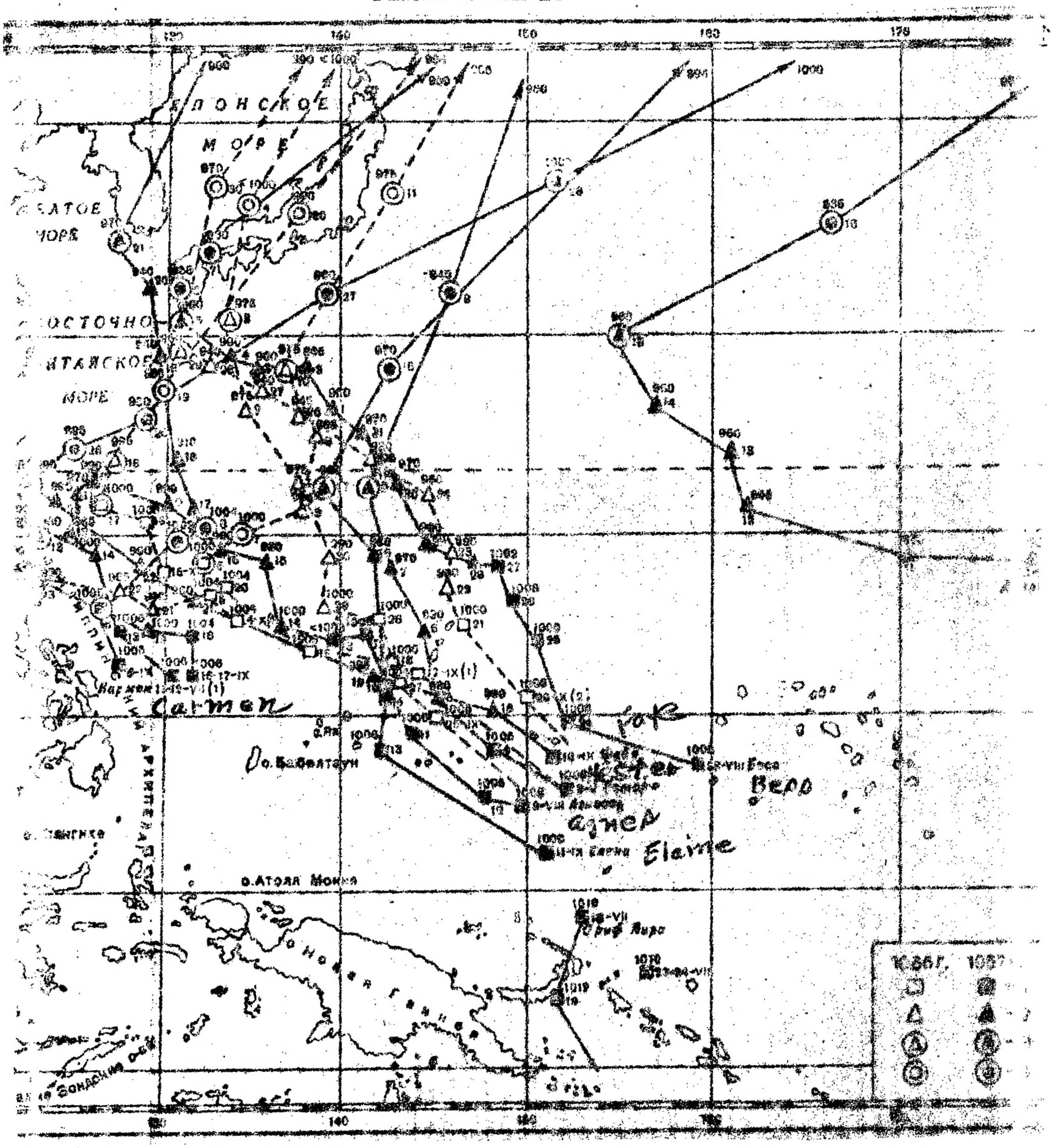

Figure 1. Trajectory of cyclones. Stages of development of typhoons. 1, tropical depression; 2, typhoon; 3, moment of transformation; 4, transformed typhoon. Numbers signify dates and pressure at center.

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END